Optical Networking in a Converged Networks Environment

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Introduction

• There is a new reality in optical networking arena characterized by the following:
  
  • Equipment and solutions should cost less, while providing more functions.
  • Technology makes sense only when benefits are clear (cost reduction, advanced functions, special needs addressed)

• Research needs truly multidisciplinary approach in a new environment of network convergence
Global Networking Highlights

- **Optical Transport Function**
- **Optical Crossconnect Function in Core Node**
- **Multi-Function (Multiservice) Edge Node**
- **Broadband packet based access to end users**

- IP-based traffic is becoming dominant. Three concentric circles in the network can be recognized (users, edge/adaptation, and core).
- Optical Networking: intelligence with automatic provisioning (QoS, survivability, and manageability provided)
- Various services (Triple play, IPTV, VPN, etc.)
Bigger Picture of Overall Networking

All Optical Core
Intelligence through MPLS/GMPLS

Submarine

Metro

Multiservice Intelligent Edge

- Copper Access (xDSL)
- Fiber Access (xPON)
- Wireless Access

Major POP centers
The diagram illustrates the Envisioned End-User Bandwidth Consumers in a Broadband Communications Era. There are several competing technologies for the delivery of services, including:

- Internet
- Leased Line
- Frame/Cell Relay
- Telephone
- Interactive Video

These technologies are categorized into Business and Residential sections, each with access methods such as Fiber (FTTH), Cable, Twisted Pair (xdsl, pots), Fixed Broadband Wireless, and Satellite. The diagram also shows the Home Distribution Networks, including options like Power Line (HomePlug) and Wireless (802.11, 802.15.3, Bluetooth, BT 2.0).
Next Gen Networks (NGN) Services

- Three types of services in NGN:

1. Connection oriented service over Circuit
2. Connectionless service over Packet
3. Connection oriented service over Packet

“Connection” represents Revenue opportunity.

“Packet” represents Network efficiency.

Large capacity, High Reliability
NEC Network Architecture for the Next Generation Services Delivery

RPR-based effective packet aggregation for VoD service (Best effort/ Prioritized QoS)

Lambda/TDM Hierarchical Multicast for real-time TV distribution (Guaranteed / Exact QoS)
Optical Networking
Topics and Technologies

New Technologies and Current Reality:
• Transmission capacity options (10/40 >>160 Gb/s)
• Employment of different components for the same end-goal
• The same fiber feeder for different purposes
• Optical bandwidth pipe to majority of users
• Older and new solutions should interoperate and work together

Optical Network Monitoring and Surveillance
• How to monitor key network parameters in optical analog environment
• How to handle different bit rates; (it should be “bit rate flexible”, if possible)

QoS and Security
• How to differentiate them in all optical and in O/E/O environment

Network Intelligence must be efficient, yet as simple as possible
Optical Domain Expansion in Networks

**Big Bang of Optical Domain**

**STEP 1**
- SONET ring with WDM
- Regional optical network (Metro)

**STEP 2**
- Core network
- OEO or back to back TPND
- Metro network

**STEP 3**
- Core Network
- Metro Network

**We are here now!**
Bandwidth Connections: Directed Optical Lightpaths or Multipoint Cloud

A number of lightpaths with distinct characteristics can be established in optical network environment. If simplified, it is either point to point, or broadcast and select.
Example: Optical Equipment for Next Gen Networks

SpectralWave®
DW4240 Reconfigurable OADM
Metro Core/Edge ROADM

Automatic Gain Flatness allows easy $\lambda$ expansion and network configuration upgrades without manual gain adjustment or complicated system redesign work.

Versatile Interfaces
Gig-E, 10Gig-E Fiber Channel SONET/SDH

Optical Layer Protection on a $\lambda$ basis with 50 ms switching time.

Point-to-Multipoint Optical Layer Video Distribution.

Remotely controllable $\lambda$ add, drop or pass-through at any node, for any $\lambda$. 
Example: WXC Network/Node Configuration
Example: GUI Design for WXC Node
Example: RZ-DPSK Transmitter Device

40G Devices for Transmitter
- LN Modulator (Tandem MZ)
- Data DRV
- Clk DRV
- Clk Multiplier

40G RZ-DPSK Optical Output Waveform 10 ps/div
Example: PLC based full-band wavelength tunable laser

- Full C/L band wavelength tunable operation
- Stable single mode operation guaranteed by three-stage waveguide ring resonator
- High reliability: No moving parts, PLC based stable phase shifters
- Small chip size to be mounted in butterfly package
Example: Raman Amplifiers

Experimental Setup

Optical Spectra with and without Raman pump.
Example: 43 Gb/s Compact Pin-TIA Module

Features

- Compact
- Ease-of-Use Interfaces
  - Feedthrough Launcher
  - Receptacle Structure
- High Performances

43 Gb/s Pin-TIA Module
Example: Electric Dispersion Compensator for PMD

EDC Module

PMD impact can be greatly reduced by a proper compensation scheme
**Example: High Speed InP HBT**

**100 Gb/s Error-Free Operation**

- **100 Gb/s**
  - (V: 200 mV/div, H: 10 ps/div)
- **50 Gb/s**
  - (V: 200 mV/div, H: 10 ps/div)
- **12.5 Gb/s**
  - (V: 500 mV/div, H: 10 ps/div)

**Bit Error Rate:** <10\(^{-13}\)

**Chip Size:** 1.9 X 1.76 mm

**D flip-flop**

**ED:** Error Detector

**PPG**

**4:1 MUX**

**Selector IC**

**D-FF**

**1:4 DMUX**

**ED**

**SG**

**DIV**

**PS**

**60-cm coaxial cable**

[Diagram showing the connection of various components and the data rates]
Example of Achievement: 10.9 Tb/s Transmission

- **273 channels**
- **L-band: 96 channels**
  - 1570.01 nm ~ 1610.06 nm
- **C-band: 92 channels**
  - 1526.83 nm ~ 1563.05 nm
- **S-band: 85 channels**
  - 1476.81 nm ~ 1508.01 nm

- ** Odd 43 channels **
  - **LD1**, **LD2**, ..., **LD5**
  - LN-MOD
  - PM-AWG
  - LN-MOD
  - 40 Gb/s NRZ 2^9-1 PRBS

- ** Even 42 channels **
  - **LD2**, **LD3**, ..., **LD8**
  - LN-MOD
  - PM-AWG
  - LN-MOD
  - 40 Gb/s NRZ 2^9-1 PRBS

- ** DFB-LD control **
- ** PC **
- ** Multi-wavelength meter **

- ** 117 km **
- ** repeater **
- ** PSCF 40km **
- ** RDF 19km **
- ** GS-EDFA **
- ** EDFA **
- ** GS-TDFA **

- ** LD84 **
- ** GS-TDFA booster **
- ** PBS **

- ** 40 Gb/s ETDM Receiver **
- ** DCF **

- ** Wavelength/polarization demultiplexer **

- ** -2 dBm/ch **
  - S-band
- ** -3 dBm/ch **
  - C-band
- ** -4 dBm/ch **
  - L-band

- ** Even 42 channels **
  - ** LD2 **
  - ** LD3 **
  - ** LD4 **
  - ** LD8 **
  - ** LD9 **

- ** Odd 42 channels **
  - ** LD3 **
  - ** LD4 **
  - ** LD8 **
  - ** LD9 **

- ** LN-MOD **
- ** PM-AWG **

- ** Multi-wavelength meter **

- ** error free transmission **

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Empowered by Innovation
Research Priorities

A new direction for research needs to be set up with respect to advanced optical communication systems and networks in order to accommodate network convergence.

Priorities can be characterized by the following:

• An intense signal conditioning and processing at the optical layer
• Very large scale optoelectronic integration at the component level
• Comprehensive intelligence for both transmission and networking purposes
Future Optical Network Concept: Technologies and Techniques

• Long Haul/Metro Transport
  • Increase spectral efficiency through new modulation formats
  • Increase robustness with new cost efficient coding/monitoring
  • Adjustment and fine tuning on the spot
  • Speed up the fast signal processing
  • Enhance Optical Add Drop Multiplexers and speed up OADM/OXC convergence
  • Introduce Optical Packet Routers (with Photonic MPLS)

• Converged Environment at the Edge/Access
  • Optical edge enhancement and extension to access
  • Optical/wireless convergence in FMC environment

• Next Generation Components/Methods:
  • Tunable lasers and filters, and adjustable components (chromatic dispersion compensation, etc.)
  • Optical 3R, and optical memories
  • Optical waveguide based devices
  • New optical amplifiers
  • Others, not directly related to networking, such as quantum computing, and optical cryptography
Network Convergence

Network Convergence is a synonym used very often in discussion related to NG Networks. Convergence is related to the following:

• Geographical convergence, with networking solutions covering multitude of distances.

• IP-Optical convergence, with solutions including several logical layers (Layer 1 to Layer 3+)

• Optical-Wireless convergence, with solutions providing seamless operation in Fixed-Mobile Convergence (FMC) area.
Converged Network – a Bigger Picture
Example: NEC Optical-Wireless Testbed
Example: Network Simulations
Summary

• Telecommunication networks are in transition towards a next generation architecture that will accommodate converged network environment.

• Transmission and networking technologies are in the process of a seamless integration
  
  – Transmission
    • *technologies will provide increase in bandwidth and capacity*
    • *technologies will provide intense signal processing*

  – Networking
    • *Converged Network will be in place with advanced IP over optical and wireless, offering Flexible Bandwidth Pipes wherever and whenever needed*

    • *Control plane with unifying and dynamic philosophy will address many of operating issues*

    • *QoS and Security are part of networking*
Thank you!